THE ROLE OF SHRUBS ON REDISTRIBUTION OF MINERAL NUTRIENTS IN SOIL IN THE MOJAVE DESERT[1]

E. M. Romney[2], A. Wallace[2], H. Kaaz[2], and V. Q. Hale[2]

Abstract.— Soil profiles underneath shrub clumps and bare desert pavement were examined at 62 study sites located in both open and closed drainage basins of the northern Mojave Desert. Highly significant differences occurred in the root zone underneath shrub clumps with higher concentrations of the following soil properties: electrical conductivity (EC25°), Na, K^+, Ca^{++}, Mg^{++}, Cl^-, NO_3^-, and $SO_4^=$; exchangeable K^+; cation exchange capacity; organic C and N; available P, and DTPA-extractable Fe and Mn. These differences reflect differential cycling caused by different plant species. The decomposition and mineralization of litter deposited underneath the perennial vegetation can account for these differences in soil properties which, collectively, increase the fertility of the soil underneath the vegetation canopy. Aboveground biomass of shrubs was measured and the nitrogen and mineral element composition of new photosynthetic tissue was determined. Estimates from a representative study site indicate that the reservoir of nitrogen and mineral nutrients in new leaf material of shrubs available for litter deposition could contribute 3.64 kg N, 0.31 kg P, 0.57 kg Na, 5.20 kg K, 4.95 kg Ca, 31.82 g Fe, and 4.30 g Mn per hectare. This source probably represents about one-third of the total amount of nutrients involved in annual turnover for the study area during a normal production year. The remaining contribution would be supplied from the standing dead wood in shrubs and as litter from annual plant species.

Efforts to develop the potential benefits of wildland shrubs have increased with man's needs to make arid and semiarid lands more productive and useful. An extensive world literature produced from studies on production and mineral cycling in terrestrial vegetation was summarized in the work of Rodin and Bazilevich (1965), which considers several aspects of mineral involvement in plant production between vegetation types representing the broad climatic zones of the world. A review of available literature on the biology and utilization of wildland shrubs in arid and semiarid lands was one of the main objectives of a recent international symposium (McKell et al. 1971). At that symposium Charley (1971) discussed the role of shrubs in nutrient cycling, with emphasis upon the nitrogen conditions encountered in a perennial saltbush ecosystem. The principles governing important transformation processes involved in shrub production, litter fall, and subsequent decomposition and mineralization in natural ecosystems have been well covered in these and other recent reviews (Rennie 1955, Ovington 1962, 1965, Egunjobi 1969).

This paper reports on the influence of shrubs on cycling or redistribution of mineral nutrients in zones near roots in the Mojave Desert. Edaphic factors are important in the distribution of plant species, but plants also are important in determining soil characteristics. For example, an accumulation of nitrogen and mineral elements in plant foliage results in the cycling of these elements from litter to the soil underneath the plant canopy (Roberts 1950, Fireman and Haywood 1952, Beadle et al. 1957, Rickard 1965b, Charley and Cowling 1968, Chatterton and McKell 1969, Jessup 1969, Garcia-Moya and McKell 1970, Charley 1971, Sharma and Tongway 1973, Tiedemann and Klemmedson 1973). The extent to which this process occurs under northern Mojave Desert conditions was one aspect of concern in studies undertaken in southern Nevada.

[1]Findings in this paper appeared, with slight modifications, in The belowground ecosystem: a synthesis of plant-associated processes. Pages 303–310 in Range Science Department Science Series report No. 26. Colorado State University, Fort Collins 1977. We present these findings again for convenience and accessibility to readers interested in the several related papers in this issue.

[2]Laboratory of Nuclear Medicine and Radiation Biology, University of California, Los Angeles, California 90024.

Description and Methods

Investigations were conducted at the USAEC Nevada Test Site to obtain more information on soil and plant relationships in the desert ecosystem to better understand the impact of nuclear testing on the natural environment. The findings presented herein were synthesized from preliminary raw data reported by Romney et al. (1973).

The perennial vegetation of the study areas exists as solitary shrubs or as discrete clumps consisting of several different shrub species. Sharp ecotonal demarcation zones are prevalent among some of the more dominant shrub species. Most of the soils examined have developed on alluvium consisting of limestone or mixed limestone and volcanic material. Except in areas of recent sedimentary deposition, many are now underlaid by layers of restrictive hardpan formed from the processes of alkaline hydrolysis at depths varying from 30 to 70 cm. Study sites were selected in both open and closed drainage basins. Details of the study areas involved in these investigations have been reported (Wallace and Romney 1972, Romney et al. 1973).

At each of 62 study sites a trench was dug with a backhoe extending across a shrub clump and out into the bare desert pavement to a distance of at least 3 m. This was done to permit an examination and sampling of the soil profile underneath both shrub and bare areas in order to investigate the modifying influence of perennial vegetation on the profile horizons. The soil profiles were described according to the USDA Soil Conservation Service nomenclature (Soil Survey Staff 1951). Represented among these study sites were soil belonging to several subgroups, including Typic Torripsamments, Haplic Nadurargids, Entic Durorthids, and Typic and Duric Camborthids.

Physical and chemical properties were determined on soil samples screened to pass a 2 mm sieve. Sand fractions were measured by mechanical separation on standard testing sieves. Silt and clay fractions were determined by the pipette method described by Day (1965). Available phosphorus was extracted with sodium bicarbonate and determined colorimetrically using the method of Olsen et al. (1954) as described by Chapman and Pratt (1961). Lime content was determined by the manometric method of Williams (1948). The available micronutrients were extracted with DTPA chelate and determined by atomic absorption analysis (Lindsay and Norvell 1978). Organic nitrogen analysis was by the Kjeldahl method (Bremner 1965). The analytical methods used to determine other physical and chemical properties were those of the USDA Salinity Laboratory Staff (1954).

Some of the ecological attributes of the perennial vegetation were determined by nondestructive dimensional measurements (Wallace and Romney 1972:250). Briefly, 2 m × 25 m quadrats were laid out at right angles to each other in undisturbed vegetation in the proximity of the soil sampling trench. All shrubs within the quadrats were identified by species and measured for height and width (mean of two dimensions). These measurements were used to determine shrub density, frequency, relative dominance, cover, and volume. Biomass estimates were derived from regressions of dry weight on volume indexes developed from the destructive sampling of shrubs in nearby areas (Romney et al. 1973). Measurements of new photosynthetic production were made for the more prominent shrub species by destructive sampling at selected study sites during the peak of seasonal leaf flush.

Samples of clean foliage were collected in the vicinity of each soil sampling trench for chemical analysis. Oven-dried (70 C) samples were separated into leaf and stem material and finely ground for analysis by optical emission spectrometry (Wallace and Romney 1972:363). Total nitrogen contents were determined on leaf tissue using the Coleman Model 29A Nitrogen Analyzer.

Results and Discussion

Soil Profile Characteristics

Most of the soil profiles examined in this study have developed on relatively coarse alluviums low in clay content under conditions of high temperature and low rainfall. Many profiles clearly indicate an acceleration of the soil-forming processes underneath shrub clumps. Distinct differences also occur in the amounts of wind-blown material deposited underneath shrubs and on bare soil. Loess blankets a major portion of the study area (Ekren 1968); volcanic ash falls and wind action are responsible for its wide distribution. Other prominent characteristics evident under shrubs include better developed A horizons containing higher concentrations of salt and organic matter, and some decomposition of the underlying hardpan when present. Table 1 contains the profile description for study site No. 5, which is representative of soils with an underlying hardpan developed on alluvium parent material of mixed limestone and quartz. Detailed descriptions and properties of other soil profiles are given in Romney et al. (1973).

Physical and chemical properties of the soil profile at site No. 5 are listed in Table 2. They reflect the kinds of change generally found between different horizons underneath shrub clumps and bare areas. These properties most notably modified in zones near roots include the salts of sodium, potassium, calcium and magnesium, available phosphorus, organic carbon and nitrogen, and available iron and manganese. The particle size distribution, water-holding capacity, pH, and lime content essentially remained unaltered within the depth of the root zone. Electrical conductivity (EC25°) of the saturation extract reflected the concentrations of soluble cations and anions in the profile horizons. Highest salt concentrations were found in the A horizons underneath shrubs. No evidence was found of an accumulation of soluble salts in the bare soil areas between shrub clumps as reported by Charley and McGarity (1964) for perennial saltbush communities growing on saline soils of the Australian arid zone. The soils examined here are moderately permeable and subject to leaching by rainfall. Except for a few sites located on sediments of closed-drainage basins, most profiles examined were nonsaline-nonalkali within the root zone, i.e, the EC25° was less than 4 mmhos/cm and the exchangeable sodium percentage was less than 15 (U.S. Salinity Laboratory Staff 1954).

Several other investigators have described sharp changes in the chemical properties of soil underneath shrub canopies resulting from an accumulation of salts as the result of litter deposition (Roberts 1950, Fireman and Hayward 1952, Rickard 1965a, 1965b, Charley and Cowling 1968, Sharma and Tongway 1973). Similarly, significant accumulations of nitrogen and organic matter have occurred as the result of litter decomposition (Garcia-

TABLE 1. Soil profile description at Mercury Valley Study Site No. 5.

Area: Mercury Valley, Nye County, Nevada

Perennial vegetation: *Acamptopappus shockleyi* A. Gray, *Atriplex confertifolia* (Torr. & Frem.) Wats., *Ambrosia dumosa* (A. Gray) Payne, *Ephedra funerea* Cov. & Mort. *Ephedra nevadensis*, Wats., *Ceratoides lanata* (Pursh) J. T. Howell, *Grayia spinosa* (Hook) Moq., *Krameria parvifolia* Benth., *Larrea tridentata* (Sesse & Moc. ex DC.) Cov., *Lycium andersonii* A. Gray., *Yucca schidigera* Roezl ex Ortgies.

Parent material: alluvium from limestone and quartz.

Topography: 3 percent southwest slope, smooth relief; well-drained moderate erosion; surface about 80 percent rock and gravel; well-developed desert pavement; elevation 1096 m.

Profile under shrub clump: (*C. lanata, L. tridentata, L. andersonii*)

A1	0–9 cm	Brown (10YR5/3) loamy fine sand, brown to dark brown (10YR4/3) moist; weak fine subangular blocky structure; soft, friable, nonsticky, violently effervescent; few micro roots; pH 8.0; abrupt smooth boundary.
A2	9–13 cm	Very pale brown (10YR7/3) sandy loam, yellowish brown (10YR5/4) moist; moderate medium platy; slightly hard, friable, slightly sticky; violently effervescent; few medium, fine, and micro roots; 20 percent gravel; pH 8.4; abrupt irregular boundary; discontinuous.
C1	13–36 cm	Very pale brown (10YR7/3) loamy sand, yellowish brown (10YR5/4) moist; weak fine subangular blocky structure; soft, friable, nonsticky, violently effervescent; few medium, fine, and micro roots; 20 percent gravel; pH 8.4; clear wavy boundary.
C2sicam	36+ cm	Cemented pan.

Profile under bare area:

C1		Horizon description is the same as C1 under shrub.
C2sicam	34+ cm	

Moya and McKell 1970, Charley 1972, Tiedemann and Klemmedson 1970, Holmgren and Brewster 1972, Nishita and Haug 1973). The work of Charley and Cowling (1968) indicates that biologically increased vertical salt gradients in soil seem to become sharper with increased aridity.

Perennial Vegetation Characteristics

Some of the ecological attributes of shrubs at study site No. 5 are given in Table 3. Beatley (1969a) described the vegetation type and association for the area in which this site was located as *Larrea-Franseria* (*Ambrosia*). Nondestructive dimensional measurements indicate *Acamptopappus shockleyi* A. Gray and *Ambrosia dumosa* (A. Gray) Payne were of highest density and frequency. The relative dominance index for basal area was highest for *A. dumosa* followed closely by *Lycium andersonii* A. Gray and *Krameria parvifolia* Benth. Greatest aboveground standing biomass was contributed by *Yucca schidigera* Roezl ex Ortgies (927 kg/ha). *Lycium andersonii* and *A. dumosa* contributed essentially the same biomass (458 and 456 kg/ha) followed by *Ephedra funerea* Cov. and Mort. (228 kg/ha), *Larrea tridentata* (Sesse & Moc ex DC.) Cov. (162 kg/ha) and *K. parvifolia*

TABLE 2. Physical and chemical properties of soil profile horizons under shrub and bare areas of site no. 5.

Profile horizon	Shrub clump			Bare area
properties	A1	A2	C1	C1
Horizon depth, cm	0–9	9–13	13–36	0–34
Particle size distribution (% < 2mm)				
coarse sand (2.0–0.25)	28.8	26.2	21.0	25.5
fine sand (0.25–0.05)	53.9	41.3	56.7	50.2
silt (0.05–0.002)	10.9	23.4	16.2	16.9
clay (< 0.002)	6.4	9.1	6.1	7.4
Percent moisture retention				
saturation	44.7	26.6	32.8	26.2
–0.3 bar	15.7	17.7	19.5	16.5
–1 bar	13.4	14.5	15.3	14.7
–15 bar	9.6	8.7	7.8	8.1
pH (saturated paste)	8.0	8.4	8.4	8.3
EC (mmhos per cm, 25 C)	4.74	1.49	0.55	0.40
Saturation extract soluble cations and anions				
Na, meq/1	2.50	8.32	1.84	0.56
K, meq/1	13.20	2.95	1.65	0.63
Ca, meq/1	19.69	5.14	0.56	0.76
SO_4, meq/1	1.00	0.14	0.02	0.07
B, ug/g	5.10	3.60	0.10	2.90
Exchangeable cations (NH_4OAc-extraction)				
Na, meq/100 g	0.27	0.71	0.42	0.47
Na, %	1.50	4.10	2.50	3.00
K, meq/100 g	4.06	3.92	3.45	1.78
Ca + Mg, meq/100 g	13.17	12.87	13.01	13.38
C.E.C., meq/100 g	17.50	17.50	16.88	15.63
Percent lime (< 2mm)	16.00	17.00	17.00	17.00
P, ($NaHCO_3$-ext.) ug/g	3.26	0.36	0.04	0.24
Organic carbon, %	2.12	0.48	0.38	0.33
Organic nitrogen, %	0.211	0.050	0.044	0.035
DTPA-extractable micronutrients				
Fe, ug/g	0.5	0.1	0.2	0.1
Zn, ug/g	0.80	0.80	0.80	0.95
Cu, ug/g	0.20	0.30	0.20	0.25
Mn, ug/g	5.00	1.50	1.15	0.95

(148 kg/ha). These shrubs accounted for more than 95 percent of the perennial plant biomass. In this particular area, dead wood often accounts for a significant portion of the standing biomass of perennial vegetation. It remains standing for many years and probably contributes about as much mass in annual litter-fall as does new leaf material.

Leaf/plant ratios were measured for most shrubs at this site during peak leaf flush in 1968. *Yucca schidigera* was ignored because of its lack of contribution to mobile leaf litter

TABLE 3. Characteristics of perennial vegetation at study site no. 5.

Plant species	Density No/ha	Frequency %	Relative dominance*	Biomass** kg/ha	Leaf/Plant ratio**
Acamptopappus shockleyi	3589	25.6	8.4	26.1	0.137 (19)***
Ambrosia dumosa	3274	23.3	23.9	456.5	0.689 (38)
Atriplex confertifolia	356	2.5	1.4	61.6	0.156 (8)
Ephedra funerea	452	3.2	7.9	228.6	—
Ephedra nevadensis	561	4.0	4.0	63.0	0.010 (10)
Eurotia lanata	863	6.2	2.6	52.5	0.080 (22)
Grayia spinosa	123	0.9	0.6	15.3	0.135 (18)
Krameria parvifolia	1178	8.4	15.5	148.6	0.188 (17)
Larrea tridentata	561	4.0	7.0	162.7	0.081 (13)
Lycium andersonii	1000	7.1	19.3	458.6	0.054 (13)
Yucca schidigera	109	0.8	5.7	927.1	—

*Index of basal area occupied by species. Ground cover estimate from nondestructive, dimensional measurements was 24.8 percent.
**Measurements were made of aboveground parts of shrubs at peak of new leaf flush, 1968.
***Number of shrubs from which mean ratio was determined.

TABLE 4. Nitrogen and mineral element composition of perennial vegetation from study site no. 5.

Plant species	Plant part*	N %	P %	Na %	K %	Ca %
Acamptopappus shockleyi	leaf	2.98	0.25	0.161	4.43	1.68
	stem		0.17	0.110	3.32	1.52
Ambrosia dumosa	leaf	4.16	0.37	0.114	5.48	2.98
	stem		0.24	0.111	4.07	1.58
Atriplex confertifolia	leaf	2.96	0.39	4.414	6.84	3.95
	stem		0.27	1.960	2.21	2.52
Ephedra funerea	shoot	2.32	0.12	0.028	1.17	2.55
Ephedra nevadensis	shoot	2.94	0.32	0.008	2.37	1.18
Ceratoides lanata	leaf	3.62	0.22	0.037	3.69	1.42
	stem		0.09	0.005	3.99	0.52
Grayia spinosa	leaf	2.23	0.09	0.175	10.13	4.25
	stem		0.08	0.009	6.06	1.23
Krameria parvifolia	leaf	2.10	0.31	0.316	2.13	1.23
	stem		0.24	0.127	2.12	0.87
Larrea tridentata	leaf	2.56	0.16	0.103	2.13	1.53
	stem		0.07	0.088	1.18	1.10
Lycium andersonii	leaf	3.26	0.12	0.013	5.58	11.64
	stem		0.10	0.010	2.12	2.65

*Samples harvested at peak of leaf flush, 1969.

due to growth habit. There was no significant increase of new shoots on *E. funerea* in 1968. It should be noted here that annual photosynthetic production in this ecosystem differs markedly from year to year, depending upon seasonal rainfall and temperature conditions (Beatley 1969b, Wallace and Romney 1972). New leaf production in 1968 was considered to be about normal for this area. Calculations based upon these biomass and leaf/plant ratios indicate that the total contribution of new leaf material available for litter deposition from shrubs was 107.4 kg/ha in 1968. The biomass of annual plants was not measured at this site, but Beatley (1969b) reported total winter annual plant biomass values for a nearby study plot of 60.58, 21.73, and 174.16 kg/ha for 1964, 1965, and 1966, respectively.

The nitrogen and mineral element composition of perennial vegetation sampled at the peak of leaf flush in 1969 is shown in Table 4. The nitrogen composition of leaf tissues varied among species but fell within the range commonly found in cultivated pasture crops (2.5 to 3.5 percent). Phosphorus contents varied within the range of 0.10 to 0.40 percent, and higher levels usually occurred in leaf than in stem tissues. Sodium concentrations were relatively low in plant tissues grown at this site; however, *A. dumosa*, *Grayia spinosa* (Hook.) Moq., *L. andersonii*, and, of course, the *Atriplex* species have the capacity to concentrate much higher levels of sodium than is present in the soil (Wallace and Romney 1972, Romney et al. 1973). Potassium is one of the most variable of the nutrient elements in these desert shrubs; its concentration in stem tissues often reaches or exceeds that found in leaf tissues. *Ambrosia dumosa*, *Ceratoides lanata* (Pursh) J. T. Howell, and *L. andersonii* consistently contain relatively high levels of potassium, and *G. spinosa* usually contains exceptionally high concentrations. High concentrations of calcium and strontium are normally found in

Table 4 continued.

Mg	Si	Zn	Cu	Fe	Mn	B	Sr	Ba
%	μg	μg	μg	μg	μg	μg	μg	μg
0.48	0.47	22	8	164	51	46	29	1
0.20	0.04	7	5	48	12	17	43	7
0.54	0.15	28	7	256	23	100	56	9
0.54	0.07	13	4	141	19	42	50	14
0.61	0.17	9	5	362	32	73	130	50
0.37	0.07	7	7	237	86	21	131	47
0.34	0.17	7	6	186	68	10	197	52
0.26	0.03	22	2	92	18	24	61	11
0.56	0.05	21	4	110	66	41	45	5
0.23	0.02	6	3	79	28	14	37	6
2.15	0.07	37	5	150	139	65	32	5
0.51	0.01	16	3	20	15	20	25	5
0.37	0.18	17	6	261	43	39	99	17
0.28	0.10	16	5	168	15	27	88	15
0.22	0.45	26	2	585	41	88	44	11
0.21	0.40	16	4	1091	33	28	54	16
1.44	0.05	41	4	162	33	65	648	18
0.24	0.04	9	3	90	5	12	77	11

leaf tissues of *L. andersonii*. Stem tissues usually contain less calcium than do leaf tissues of most shrub species. Both *G. spinosa* and *L. andersonii* leaves often contain higher contents of magnesium than do those of other species from the same location. The micronutrients and trace metals vary considerably among the various shrub species, and leaf tissues usually contain higher amounts than are concentrated in stem tissues. One striking exception to this was the consistently high iron content of leaf and stem tissues of *Larrea tridentata*, wherever sampled (Romney et al. 1973). Boron contents generally ranged from 10 to 100 ug/g.

Modifying Effects of Vegetation on the Soil Properties Near Root Zones

Inasmuch as soil properties were characterized from existing horizons of varied depths, it was necessary for statistical analysis to normalize all values to assess differences underneath shrubs and bare sites. This was done by computer synthesis to a common depth of 30 cm because most of the active root zone lies within this depth in our study areas. Comparisons were made of the statistical significance of differences between the values of properties measured underneath shrubs and bare surfaces at 62 study sites. Bare site values were subtracted from shrub site values, and the means and standard deviations for each of 22 variables were derived from these differences. For each of these variables, the mean differences were divided by the standard deviations and then multiplied by the square root of the sample number to derive a t-value. The null hypothesis that the means are not significantly different from zero was rejected if t was less than −2.000 or greater than 2.000 ($p=0.05$). With this test means that were significantly different from each other could be identified and the conclusion reached that the presence of shrubs modified the soil properties when their mean difference was positive (Table 5).

The soil properties which tended to have higher values underneath shrubs, but which were not significantly different, included water-holding capacity, pH, and exchangeable sodium. The exchangeable calcium and magnesium, lime, and DTPA-extractable zinc and copper contents tended to be higher in bare soil, but their differences were not significant. All the other soil properties tested were significantly higher under shrub clumps including the saturation extract conductivity (EC25°), the soluble cations and anions, exchangeable potassium, the cation exchange capacity, organic carbon and nitrogen, available phosphorus, and the DTPA-extractable iron and manganese.

The cycling and redistribution of carbon, nitrogen, and mineral elements from the decomposition and mineralization of litter deposited underneath perennial vegetation can account for these differences in soil properties that, collectively, increase the fertility of the soil underneath the vegetation canopy. These shrub clumps also act as catchments for windblown litter and serve as shelters for most of the annual plant species. The shrub

TABLE 5. A measure of the difference in soil properties underneath shrub and bare areas at 62 study sites.

Soil properties	Mean difference (shrub minus bare)	t-statistic*
Moisture, −0.3 bar	0.48	1.534
pH (paste)	0.08	0.528
EC_{25} mmhos/cm	1.06	10.435
Saturation extract soluble cations and anions:		
Na, meq/l	1.64	3.067
K, meq/l	2.96	9.466
Ca, meq/l	8.75	7.921
Mg, meq/l	5.06	8.131
Cl, meq/l	3.43	5.090
NO_3, meq/l	1.98	2.669
SO_4, meq/l	0.64	4.046
Exchangeable cations (NH_4OAc-extractable):		
Na, meq/100 g.	0.09	1.127
K, meq/100 g.	1.44	8.327
Ca + Mg, meq/100 g.	−0.21	−0.682
C.E.C, meq/100 g.	1.21	3.813
Lime, % < 2 mm	−0.18	−0.482
Organic C, %	0.46	11.078
Organic N, %	0.041	12.601
P($NaHCO_3$-ext.),ug/g	1.17	8.244
DTPA-extractable micronutrients:		
Fe, ug/g	0.07	4.664
Zn, ug/g	−0.07	−1.094
Cu, ug/g	−0.01	−1.492
Mn, ug/g	1.42	10.477

*$t = (\text{mean difference}/\text{standard deviation}) \times \sqrt{N}$, $N = 62$; difference is significant ($p=0.05$) where $t < -2.000$ or $t > 2.000$.

clumps that exist in our study areas are very old (Wallace and Romney 1972), so these cycling and redistribution processes probably have been underway for many centuries at any given site. Some effects of specific shrub species on the redistribution of mineral nutrients in zones near roots are illustrated in the data of Table 6.

An estimate of the annual reservoir of nitrogen and mineral elements in new leaf material available for litter deposition from study site No. 5 is given in Table 7. If all the litter remained on site, this reservoir could contribute nitrogen, 3.64 kg/ha; phosphorus, 0.312 kg/ha; sodium 0.577 kg/ha; potassium 5.20 kg/ha; calcium 4.95 kg/ha; and iron and manganese 31.82 and 4.30 g/ha, respectively. These values were calculated from new leaf production in 1968 (Table 3) and from chemical analysis in 1969 (Table 4). They probably represent about one-third of the total nitrogen and mineral nutrients involved in the annual turnover for the area during a normal year. The remaining contribution of nutrients for cycling would be supplied by litter-fall from the standing dead wood and from the litter of annual plant species. These estimates are based upon a normal production year for this ecosystem. However, two growth seasons have occurred during the past decade (1969 and 1973) in which the new photosynthetic production of many perennial species was from three to five times greater than in the other years (unpubl. data). Conversely, years have also occurred in which new production was less than one-half that of 1968. Beatley

TABLE 6. Soil properties underneath shrub and bare areas at different locations illustrating some effects of specific shrub species on redistribution of mineral nutrients in zones near roots.

	A. canescens		*A. confertifolia*		*G. spinosa*		*L. tridentata*		*L. andersonii*	
Soil properties*	Shrub	Bare	Shrub	Bare	Shrub	Bare	Shrub	Bare	Shrub	Bare
Moisture, –0.3 bar	13.1	12.1	13.4	14.9	8.8	10.4	18.9	17.1	19.4	15.9
pH (paste)	8.5	8.6	8.6	8.9	8.4	8.7	8.4	8.6	8.4	8.6
EC_{25}° mmhos/cm	3.19	0.34	2.98	0.68	1.36	0.38	2.57	0.64	3.20	0.46
Saturation extract soluble cations and anions:										
Na, meq/l	7.20	0.55	27.95	4.23	1.03	0.41	2.93	0.23	3.82	0.63
K, meq/l	15.17	1.05	3.98	1.59	13.57	0.72	4.23	1.50	6.58	0.71
Ca, meq/l	32.31	2.42	6.79	1.34	9.68	3.63	30.18	6.09	28.75	3.55
Mg, meq/l	25.54	1.05	4.80	1.22	9.94	1.86	10.99	2.31	12.80	0.43
Cl, meq/l	10.87	0.27	12.66	0.82	4.68	2.42	4.29	0.16	10.12	0.53
NO_3, meq/l	13.75	0.33	0.68	0.02	—	—	36.29	0.05	—	—
SO_4, meq/l	1.52	0.07	0.59	0.13	0.12	0.02	1.19	0.09	0.95	0.02
Exchangeable cations (NH_4OAc-extractable):										
Na, meq/100 g	0.72	0.48	3.84	1.91	0.41	0.53	0.41	0.30	0.39	0.31
K, meq/100 g	10.83	6.43	7.75	9.22	5.16	2.64	2.63	2.30	3.59	1.69
Ca + Mg meq/100 g	6.99	9.20	5.69	8.11	7.44	7.45	12.55	4.66	10.44	7.32
C.E.C., meq/100 g	18.6	16.1	17.3	19.3	13.0	10.6	15.6	13.5	14.5	9.3
Lime, % < 2 mm	5.0	3.0	7.8	7.3	1.0	1.6	13.9	15.1	17.3	25.9
Organic C, %	0.63	0.11	0.40	0.21	0.97	0.12	1.54	0.55	1.18	0.34
Organic N, × 10^{-1}%	0.84	0.12	0.37	0.22	0.90	0.14	1.31	0.63	1.19	0.31
P ($NaHCO_3$-ext.), ug/g	2.3	0.1	1.2	0.4	5.8	1.2	1.6	0.8	1.1	0.2
DTPA-extractable micronutrients:										
Fe, ug/g	0.3	0.2	0.1	0.1	0.6	0.4	0.5	0.4	0.5	0.4
Zn, ug/g	0.57	0.36	0.70	0.38	0.45	0.40	0.70	0.93	0.84	2.21
Cu, ug/g	0.28	0.27	0.17	0.26	0.15	0.10	0.26	0.25	0.13	0.15
Mn, ug/g	1.87	0.49	2.99	2.19	3.83	1.44	3.07	2.68	2.29	1.672

*Values per cm normalized to 30 cm depth under shrub clump and bare areas.

TABLE 7. Annual reservoir of nitrogen and mineral elements in new leaves of perennial vegetation available for litter deposition and mineralization at study site no. 5.

Plant species	N	P	Na	K	Ca	Mg
			kg/ha*			
Acamptopappus shockleyi	0.11	0.009	0.006	0.19	0.06	0.02
Ambrosia dumosa	1.29	0.115	0.035	1.70	0.93	0.17
Atriplex confertifolia	0.28	0.037	0.424	0.66	0.38	0.06
Ephedra nevadensis	0.02	0.002	0.001	0.02	0.01	0.01
Ceratoides lanata	0.15	0.009	0.002	0.16	0.06	0.02
Grayia spinosa	0.05	0.002	0.004	0.21	0.09	0.04
Krameria parvifolia	0.59	0.087	0.088	0.60	0.34	0.10
Larrea tridentata	0.34	0.021	0.014	0.28	0.20	0.03
Lycium andersonii	0.81	0.030	0.003	1.38	2.88	0.36
Total	3.64	0.312	0.577	5.20	4.95	0.81

*Calculations based on biomass estimates for 1968 and chemical analyses for 1969; sum of total elements is 15.76 kg/ha.

(1969b) reported enormous yearly variations in winter annual production in this ecosystem. The nitrogen values in these estimates fall within the range of values for shrubs of a low-fertility desert area reported by Garcia-Moya and McKell (1970) and for a saltbrush community reported by Charley and Cowling (1968). These mineral element estimates are in the same range of some values for desert zones reported by Rodin and Bazilevich (1965).

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LITERATURE CITED

BEADLE, N. C. W., R. D. B. WHALLEY, AND J. B. GIBSON. 1957. Studies in halophytes. II. Analytical data on the mineral constituents of three species of *Atriplex* and their accompanying soils in Australia. Ecology 38:340–344.

BEATLEY, J. C. 1969a. Vascular plants of the Nevada Test Site, Nellis Air Force Range, and Ash Meadows, USAEC Report UCLA 12-705, 122 pp.

______. 1969b. Biomass of desert winter annual plant populations in southern Nevada. Oikos 20:261–273.

BREMNER, J. M. 1965. Total nitrogen. Pages 1149–1178 *in* C. A. Black, ed. Methods of soil analysis, Part 2. Amer. Soc. Agron. Inc., Madison, Wisconsin.

CHAPMAN, H. D., AND P. F. PRATT. 1961. Methods of analysis for soils, plants and waters. University of California Div. Agric. Sci., pp. 262–264.

CHARLEY, J. L. 1971. The role of shrubs in nutrient cycling. Pages 182–202 *in* USDA Forest Service Tech Report INT-1.

CHARLEY, J. L., AND J. W. MCGARITY. 1964. High soil nitrate levels in patterned saltbrush communities. Nature 201:1351–1352.

CHARLEY, J. L., AND S. W. COWLING. 1968. Changes in soil nutrient status resulting from overgrazing and their consequences in plant communities of semi-arid zones. Proc. Ecol. Aust. 3:25–38.

CHATTERTON, N. J., AND C. M. MCKELL. 1969. *Atriplex polycarpa*: I. Germination and growth as affected by sodium chloride in water cultures. Agron. J. 61:448–450.

DAY, P. R. 1965. Particle fractionation and particle-size analysis. Pages 552–562 *in* C. A. Black, ed. Methods of soil analysis, Part 1. Amer. Soc. Agron. Inc., Madison, Wisconsin.

EGUNJOBI, J. K. 1969. Primary productivity and nutrient cycling in terrestrial ecosystems. Tuatara 17:49–66.

EKREN, E. B. 1968. Geological setting of Nevada Test Site and Nellis Air Force Range. Pages 11–19 *in* E. B. Eckel, ed. Nevada Test Site. Geol. Soc. Am. Mem. 110.

FIREMAN, M., AND H. E. HAYWARD. 1952. Indicator significance of some shrubs in the Escalante Desert, Utah. Bot. Gaz. 114:143–155.

GARCIA-MOYA, E., AND C. M. MCKELL. 1970. Contribution of shrubs to the nitrogen economy of a desert-wash plant community. Ecology 51:81–88.

HOLMGREN, R. C., AND S. F. BREWSTER, JR. 1972. Distribution of organic matter reserve in a desert shrub community. USDA Forest Service. Res. Paper INT-130, 15 pp.

JESSUP, R. W. 1969. Soil salinity in saltbrush country of northeastern South Australia. Trans. Roy Soc. S. Aust. 93:69–78.

LINDSAY, W. L., AND W. A. NORVELL. 1978. Development of a DTPA soil test for zinc, iron, manganese, and copper. Soil Sci. Soc. Amer. J. 42:421–428.

Table 7 continued.

Si	Zn	Cu	Fe	Mn	B	Sr	Ba
			g/ha*				
0.017	0.08	0.03	0.58	0.18	0.16	0.10	0.01
0.047	0.87	0.22	7.94	0.71	3.10	1.73	0.27
0.016	0.09	0.05	3.47	0.30	0.70	1.24	0.48
0.001	0.01	0.01	0.06	0.01	0.01	0.03	0.01
0.002	0.09	0.02	0.46	0.27	0.17	0.18	0.02
0.001	0.08	0.01	0.31	0.28	0.13	0.06	0.01
0.050	0.47	0.17	7.29	1.20	1.09	2.76	0.47
0.059	0.34	0.03	7.70	0.54	1.16	0.58	0.14
0.012	1.02	0.10	4.01	0.81	1.61	16.04	0.44
0.205	3.05	0.64	31.82	4.30	8.13	22.72	1.85

McKell, C. M., J. P. Blaisdell, and J. R. Goodin, eds. 1971. Wildland shrubs—their biology and utilization. USDA Forest Service Gen. Tech. Report INT-1. 494 p.

Nishita, H., and R. M. Haug. 1973. Distribution of different forms of nitrogen in some desert soils. Soil Sci. 116:61–58.

Olsen, S. R., C. V. Cole, F. S. Watanabe, and L. A. Dean. 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. U.S. Dept. Agr. Cir. 939, 19 p.

Ovington, J. D. 1962. Quantitative ecology and the woodland ecosystem concept. Adv. Ecol. Res. 1:103–192.

______. 1965. Organic production, turnover, and mineral cycling in woodlands. Biol. Rev. 40:295–336.

Rennie, P. J. 1955. The uptake of nutrients by mature forest growth. Plant and Soil 7:49–95.

Rickard, W. H. 1965a. The influence of greasewood on soil-moisture penetration and soil chemistry. Northwest Sci. 39:36–42.

______. 1965b. Sodium and potassium accumulation by greasewood and hopsage leaves. Bot. Gaz. 126:116–119.

Roberts, R. C. 1950. Chemical effects of salt-tolerant shrubs on soils. Fourth Internatl. Cong. Soil Sci., Trans. 1:404–406.

Rodin, L. E., and N. I. Bazilevich. 1965. Production and mineral cycling in terrestrial vegetation. Scripta Technica Ltd. Transl., Oliver and Boyd, London, 288 p.

Romney, E. M., V. Q. Hale, A. Wallace, O. R. Lunt, J. D. Childress, H. Kaaz, G. V. Alexander, J. E. Kinnear, and T. L. Ackerman. 1973. Some characteristics of soil and perennial vegetation in northern Mojave Desert areas of the Nevada Test Site. USAEC Report UCLA 12-916, 340 p.

Sharma, M. L., and D. J. Tongway. 1973. Plant induced soil salinity patterns in two saltbrush (*Atriplex* spp.) communities. J. Range Mgmt. 26:121–125.

Soil Survey Staff. 1951. Soil survey manual. U.S. Dept. Agric. Handbook, No. 18, U.S. Govt. Printing Office. 503 p.

Tiedemann, A. R., and J. O. Klemmedson. 1970. Nutrient availability in desert grassland soils under mesquite (*Prosopis juliflora*) trees and adjacent open areas. Soil Sci. Am. Proc. 37:107–111.

______. 1973. Effect of mesquite on physical and chemical properties of the soil. J. Range Mgmt. 26:27–29.

USDA Salinity Laboratory Staff. 1954. Methods for soil characterization. Pages 83–126 *in* L. A. Richards, ed. Diagnosis and improvement of saline and alkaline soils. U.S. Dept. Agr. Handbook No. 60.

Wallace, A., and E. M. Romney. 1972. Radioecology and ecophysiology of desert plants at the Nevada Test Site. National Technical Information Services, USAEC Report TID-25954.

Williams, D. E. 1948. A rapid manometric method for the determination of carbonate in soils. Soil Sci. Soc. Am. Proc. 13:127–129.